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THE PALYNOLOGY AND PALAEONVIRONMENT OF THE UPPER TRIASSIC DOLOMITIC-MARLY SEQUENCE OF DOGNA VALLEY (UDINE, FRIULI-VENEZIA GIULIA, NE ITALY) WITH REPTILE TRACKWAYS

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Key-words: biostratigraphy, Upper Triassic, Carnian, Tuvalian, Julian Alps, Southern Alps, palynology, vertebrate tracks, palaeoenvironment.

Riassunto. Vengono riportati nuovi dati e considerazioni sulla biostratigrafia e il paleoambiente di una sezione stratigrafica costituita da alternanze dolomitico-marnose del Triassico superiore affioranti nella Val Dogna (Udine, Friuli, NE Italy). In particolare è stato investigato un intervallo con uno strato contenente piste di rettili arcosauromorfi terrestri. Nel livello soprastante, quello che direttamente ricopre le impronte e' stata rinvenuta una abbondante associazione palinologica tuvalica (Carnico superiore) con *Enzonalasporites vigens*; *Vallasporites ignacii, Patinasporites densus, Zonalasporites cinctus, Pseudoenzonalasporites summus, Samaropollenites speciosus, Camerosporites secatus*; *Partitisporites* spp. Evidenze floristiche e sedimentologiche indicano un clima arido e un ambiente di deposizione costiero soggetto a ripetute emersioni.

Abstract. New data and considerations about the biostratigraphy and the palaeoenvironment of a section in the Late Triassic dolomitic-marly sequence which crops out in the Dogna valley (Udine, Friuli, NE Italy) are reported. In particular a unit with a surface bearing tracks of archosauromorph terrestrial reptiles has been investigated. In the layer immediately overlaying the track-bearing one, a rich palynological assemblage with *Enzonalasporites vigens*; *Vallasporites ignacii, Patinasporites densus, Zonalasporites cinctus, Pseudoenzonalasporites summus, Samaropollenites speciosus, Camerosporites secatus* and *Partitisporites* spp. was found, indicating a Tuvalian age (Late Carnian). Microfloral and sedimentological evidence indicate a dry climate and a coastal depositional environment subject to repeated emersions.

Introduction.

The Canale di Dogna (Dogna Channel), usually reported as "Val Dogna" (Dogna Valley), is an E-W oriented incision in the Julian Alps and is run through by the Dogna creek, near the village of Dogna, Udine Province (Fig. 1). Ladinian dolostones (Dolomia dello Sciliar), some poorly known units of Carnian age, and the Dolomia Principale (*Hauptdolomit* of German authors) outcrop in the Dogna valley (Selli, 1963; Jadoul *et al.*, 1995). The discovery of reptile tracks in the dolomitic-marly sequence cropping out in the lower Dogna valley (Dalla Vecchia, 1996a, b) created new interest in this lithostratigraphic unit. The present note concerns the stratigraphy, in particular the biostratigraphy, and the palaeoenvironment of the section containing the footprints.

G. Roghi contributed the palynological work and F.M. Dalla Vecchia the palaeoichnological study; other parts of the account were written jointly.

Stratigraphy and sedimentology.

The well bedded alternations of black marls and grey and dark grey dolostones cropping out along the lower Dogna valley were attributed to the Monticello formation by Jadoul *et al.* (1995). They are considered laterally equivalent or even coinciding with the Carnizza Formation (Jadoul *et al.*, 1995, fig. 2) which crops out at the nearby Valbruna and Cave del Predil (formerly Raibl) localities. These alternating beds appear to lie below the Dolomia Principale, but this is difficult to confirm because of the steep morphology of the valley. No biostratigraphical and palaeoenvironmental data have been published about this formation in the Dogna valley.

The Monticello formation is well exposed along the Dogna valley downstream from the aqueduct intake situated to the east of the small village of Chiout di Puppe. Near the second waterfall downstream from the intake the following succession is exposed (from the top downwards; Fig. 2A):

3) well bedded grey dolostones alternating with black marls in tabular, centimetric-decimetric layers (about 70 m); in the lower part of this unit the pelitic intercalations are more frequent and there is often evidence of mud-cracking on the upper and lower surfaces

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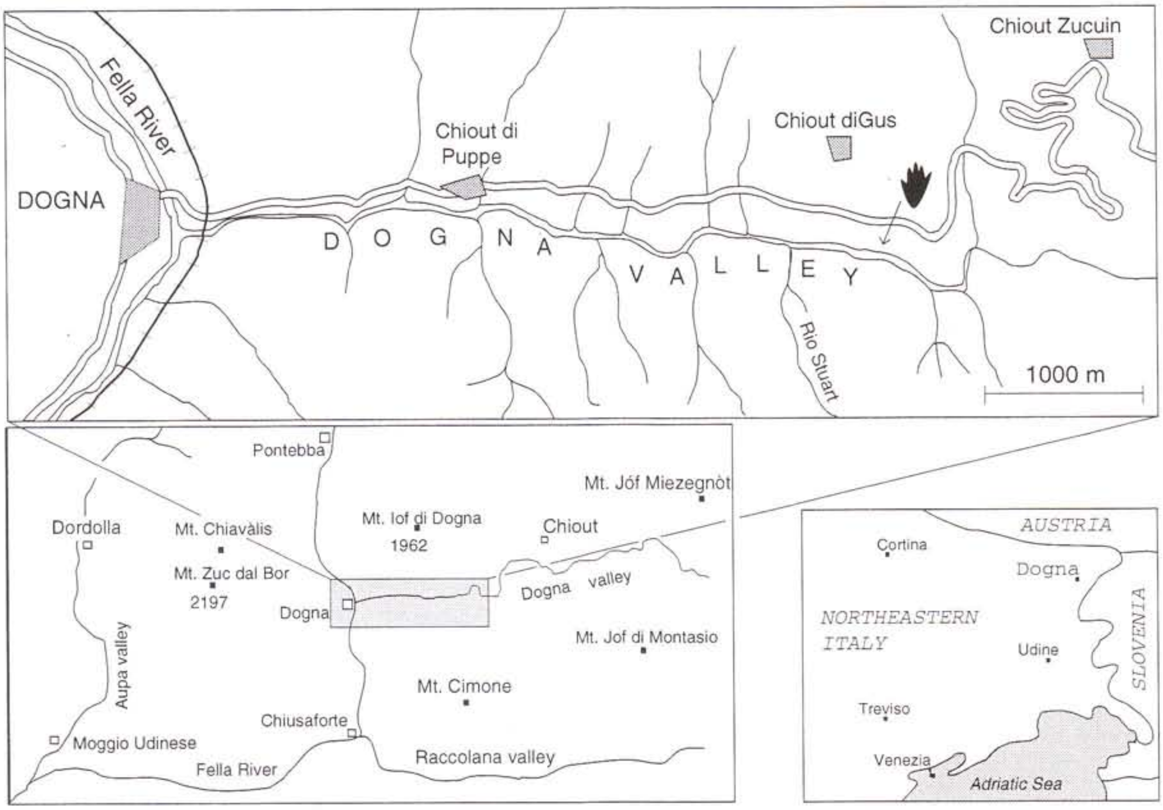

Fig. 1 - Location of the site.

of the dolomitic layers; in the study area in the Dogna valley the sequence ends at a prominent ledge which may be related to a change in lithology;

2) grey dolostones in banks with faint and irregular joints possibly representing the "orizzonte di Mestri" (Giannolla, pers. comm.; see Jadoul *et al.*, 1995) (about 20-25 m); in the upper part in a passage to the overhanging unit (3) there is a 1-3 cm-thick greenish dolostone;

1) some metres of well bedded, tabular, centimetric-decimetric alternations of grey dolostones and black marls, the lower limit of which we have not verified because unimportant for the scope of this paper.

The reptile tracks occur in the middle part of unit 3 (Fig. 2A), in the valley floor on the north side of Dogna valley, upstream from the intake of the aqueduct. The beds dip about 30°SSW. The section containing the tracks is shown in fig. 2B. At the base of the section there is a breccia layer (DGA98) with millimetric clasts, followed by two layers of marly-dolomitic mudstone (DGA99-100). The track-bearing layer (DGA100) is a disturbed mudstone with spots of wackestone at the top and deep mud-crack fissures; microfossils are completely absent. The track-bearing layer is overlain by black silty marls (DGA101) which were sampled for palynomorphs. Above this level there is a mainly marly unit with thin intercalations of sterile, black dolomitic mudstones (DGA102-103). The upper part of the section comprises beds of fine grained dolostone, sometimes separated by very thin intervals of black silty marls; structures indicating subaerial exposure (fenestrae with vadose silt) are common at this level. Ostracods are the most frequent microfossils (DGA104, 107, 108 and 110) foraminifers (*Aulotortus*?, Nodosariidae) are less common (DGA104, 105 and 110).

The depositional environment could be a restricted lagoon, represented by beds with only ostracods, sometimes more open (DGA110), which passed to a tidal flat represented by beds with fenestrae, fine grain dolomitization due to strong evaporation, perhaps stromatolitic lamination (DGA104) and with long lasting supratidal exposure represented by vadose silts. This environment was involved in the repeated arrival of pelitic sediment which was probably deposited in a reducing environment, indicated by a black colour and the presence of well preserved palynomorphs. The lack of marine fossils in the carbonate layers of the lower part of the section, where black marls are prevalent, could suggest a brackish or even fresh water environment. The frequent subaerial exposures, even in the layer with a more marked marine influence (DGA110) are noteworthy. They testify to the oscillating emersion of the zone and are in agreement with the presence of terrestrial reptiles. The Monticello formation is considered to represent deposition on the inner platform (Jadoul *et al.*, 1995) and the existence of an emergent area to the S and SW of the

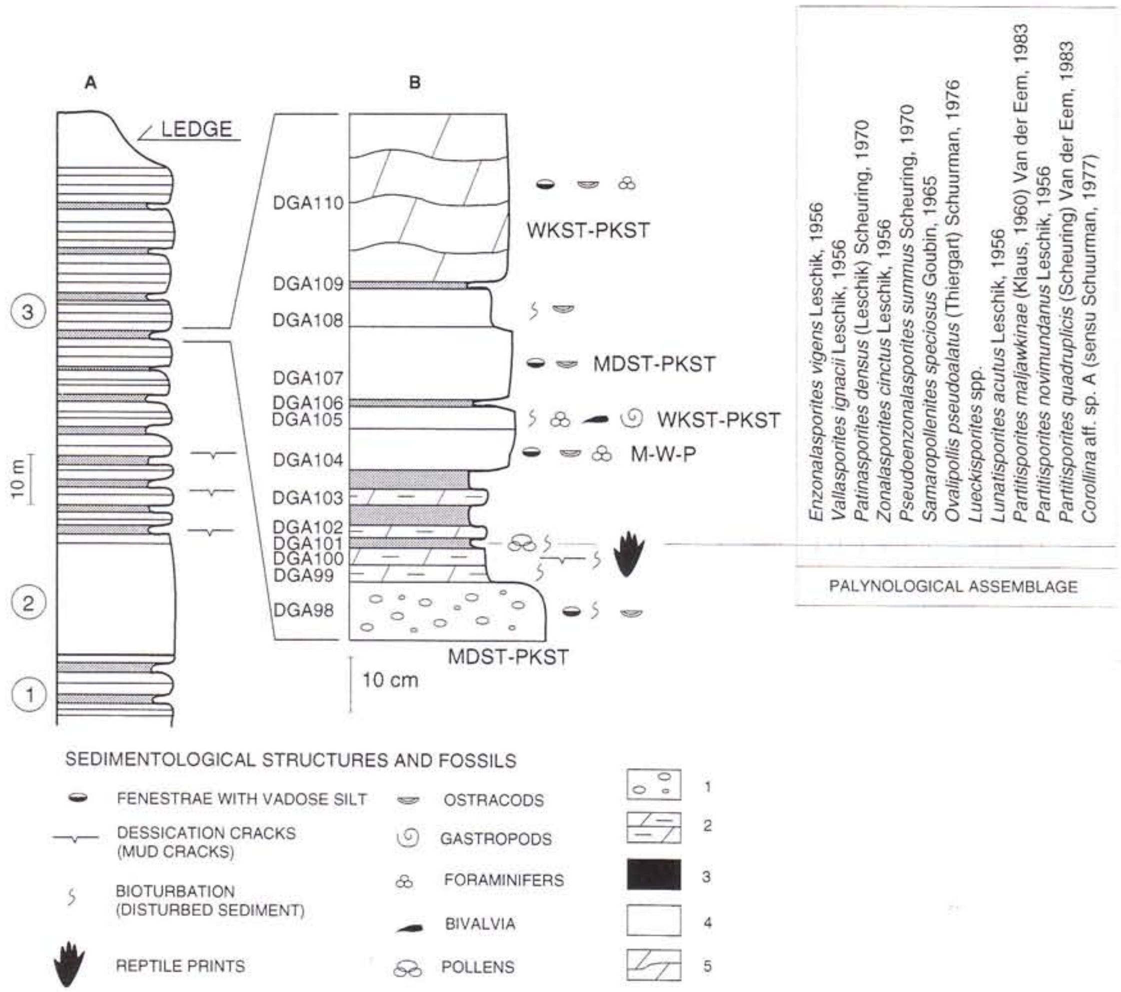

Fig. 2 - A) Schematic stratigraphic section of the observed part of the Monticello formation along Dogna Creek. 1, 2, 3 = interval number 1, 2, 3 (see text). B) the section containing the layer with the reptile tracks. Legend: 1) dark grey breccia with millimetric clasts, 2) dark grey to black marly dolostone, 3) black silty marls, 4) grey to dark grey dolostone, 5) light grey dolostone with undulating or irregular joints; MDST = mudstone, WKST = wackestone, PKST = packstone, M-W-P = bands of mudstone, wackestone and packstone.

Dogna valley during the deposition of the Carnizza Formation was suggested by the same workers (*ibidem*, p. 87).

Vertebrate Paleoichnology.

The reptile trackways were described by Dalla Vecchia (1996a, b). There are at least four trackways and two of them are 2.40 m and 2.80 m long. They were produced by a quadrupedal plantigrade reptile, with a pentadactyl pes 17-20 cm long and a tetradactyl or, most probably, pentadactyl manus at least 50% smaller than the pes (Fig. 3A,B; see also Dalla Vecchia, 1996b, fig. 3-5). The free portions of the toes are rather short, narrow and sharply pointed. Digit V is short, thin, placed rather posteriorly and is not laterally oriented but is curved forward; digits I-IV have similar lengths but digit III is the longest and I the shortest (Fig. 3A,B; see also Dalla Vecchia, 1996b, fig. 3-5). In the best preserved trackway the pace is 43-47 cm, the stride 67-72 cm and the width about 30 cm; the pace angulation of pedes is about 100°. Tracks not strongly outwardly directed, no evidence of feet dragging and absence of tracks of the tail, of the chest and of the belly indicate a relatively erect posture and a non-sprawling gait. Therefore the trackmaker was well adapted to locomotion on land. The relation between tracks and mud cracks (Dalla Vecchia, 1996b) shows that these reptiles walked across a surface on which mud was drying or had just dried (see Thulborn, 1990, fig. 5.19).

Another bed surface with mud-cracks and probable reptile tracks occurs in the creek bed, between the intake of the aqueduct and the first waterfall downstream (R. Azzola, pers. comm.). Unfortunately this bed, which is at a stratigraphically lower level, is at present covered by debris.

Track morphology and, to some extent, the parameters of the trackways are reminescent of those of the crocodiles (see Dalla Vecchia, 1996b, fig. 8) and suggest a phytosaur or primitive crocodylomorph affinity (Dalla Vecchia, 1996b).

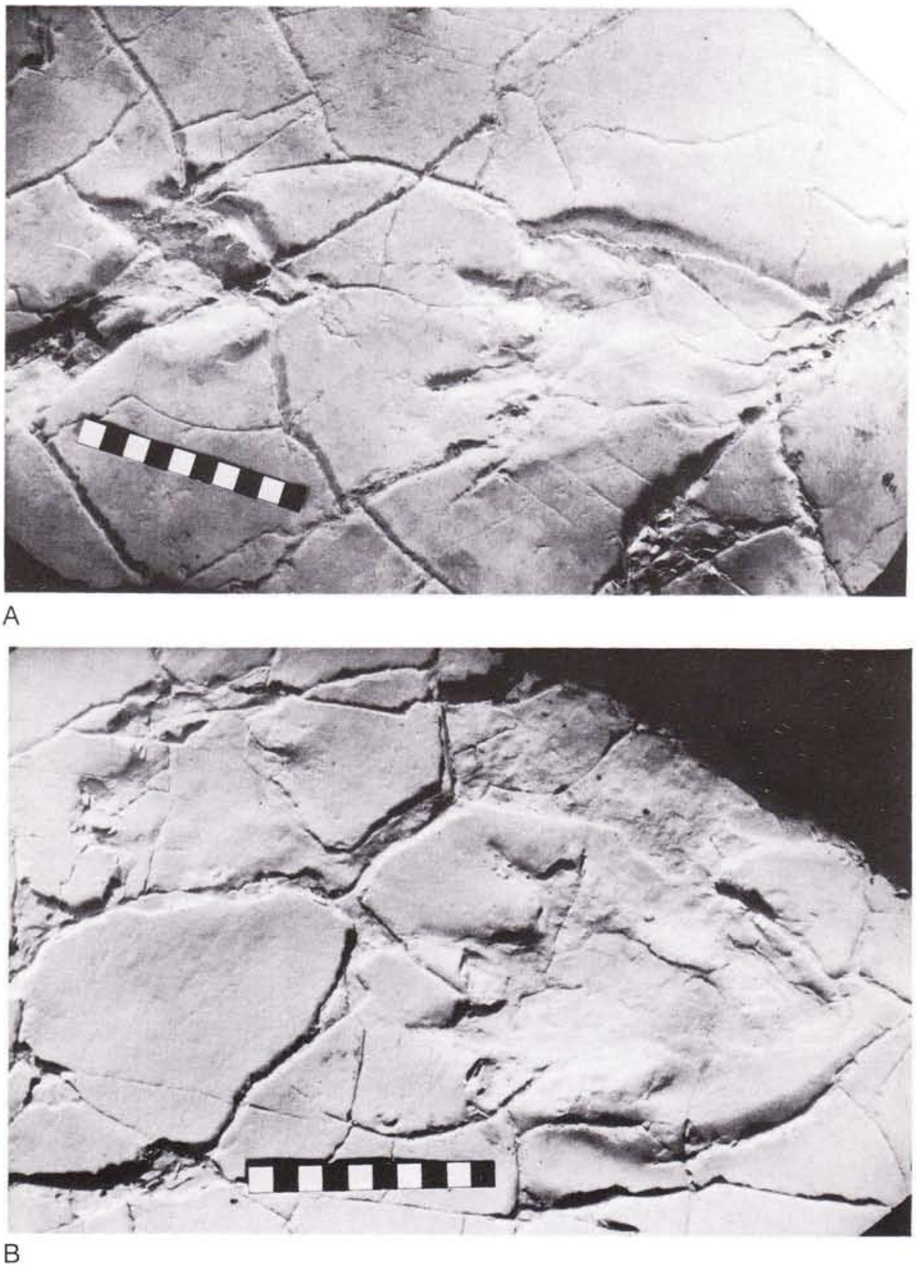

Fig. 3 - Manus-pes sets from the two main trackways. A) right set from trackway A (*cf.* Dalla Vecchia, 1996b, fig. 1), light from the left lower corner; B) right set (5th) from trackway B (*ibidem*), light from the left side. Pictures taken from silicon rubber casts of the original tracks. Scale bar: 10 cm.

The tracks do not correspond exactly to any described ichnotaxon (Haubold, 1971, 1984, 1986; Olsen & Padian, 1986). Their formal description and the institution of a new ichnotaxon is beyond the scope of this paper and will be made elsewhere (Dalla Vecchia, in progress).

Crocodylomorphs are known from Upper Carnian deposits but are relatively small, delicate reptiles represented by poor remains (Long & Murry, 1995). Primitive crocodylomorphs of the Late Triassic and Early Jurassic were small, cursorial animals. It is unlikely that the earliest crocodylomorphs were larger than the succeeding Late Triassic and Early Jurassic forms and had a body shape and posture more similar to that of present crocodiles. The pes of primitive crocodylomorphs is functionally tetradactyl, with digit V reduced to a metatarsal spur (see Dalla Vecchia, 1996b, fig. 7). The position of digit V in the pes tracks from Dogna could be in agreement with its position in the primitive crocodylomorphs but this digit is more strongly developed in those tracks.

Phytosaurs were typical Late Triassic reptiles, with a distribution ranging from the Middle Carnian in North Carolina to the Rhaetian in Switzerland, Germany, New Jersey and Connecticut; maximum diversity was reached during the Late Carnian (Tuvalian) (Benton, 1995). Even if the general shape of the pes print is similar to the reconstruction of a phytosaur footprint (Parrish, 1986, fig. 4.9A), the pedal skeletons of *Parasuchus* Lyddeker, 1885 and *Rutiodon tenuis* Camp, 1930 (see Parrish, 1986, fig. 4.4) and *Pseudopalatus pristinus* Mehl, 1928 (Long & Murry, 1995, figs 53, 55) do not correspond exactly to the footprints from Dogna valley, mainly in respect of the position and shape of digit V

(Fig. 3; cf. Dalla Vecchia, 1996b, fig. 3). Therefore, comparison should be made with a phytosaur with a digit V characteristically placed very posteriorly and such a phytosaur is not known amongst the available skeletal remains.

A third possible trackmaker considered by Dalla Vecchia (1996b) is an aetosaur. Aetosaurs were typical terrestrial quadrupedal plant-eaters of Carnian to Norian times. The oldest remains are from the ?Middle Carnian of North America, the youngest are from the "Rhaetian" of Argentina and England, with a higher diversity during Late Carnian-Early Norian (Benton, 1995, Long & Murry, 1995; Lucas & Heckert, 1996). Large aetosaurs are usually reconstructed as plantigrade and have a short and rather posteriorly placed digit V of the pes, with a curved metatarsal V. *Stagonolepis* Agassiz, 1844 and *Paratypotorax* Long & Ballew, 1985 are Late Carnian aetosaurs with a size comparable to that of the trackmaker of Dogna tracks (Long & Murry, 1995).

The rauisuchians are excluded as the potential trackmaker because of the different parameters of their trackways.

The possibility remains that the trackmaker was an unknown taxon.

Trackmaker length on the base of the body proportions of the well-known phytosaur *Parasuchus*, can be roughly estimated as slightly less than 3 m. On the basis of the reconstruction of the aetosaur *Stagonolepis* the length was about 2.5 m.

The morphological peculiarity of the tracks may make them useful for the biostratigraphic correlation of non-marine units (Haubold, 1986) and for correlation of the Monticello formation with non-marine formations.

Palynology.

The black silty marls (DGA 101; Fig. 2B) just above the track-bearing surface were sampled for palynological investigation. A rich and very well preserved miospore association was found. Seventeen taxa have been identified and a quantitative analysis on more than 200 isolated grains was made. In the sample, the miospore are organized in single grains (85%) and in tetrads (15%). Treatment of the monosaccate group follows that adopted by Scheuring (1970; 1978) and Brugman (1983) and the specimens found are in agreement with the descriptions of these authors. Some problems exist in the taxonomy of the bisaccate group. The descriptions of Van der Eem (1983) and Brugman (1983) have been used for the identification of the circumpolles; taxonomy is problematic when the grains are organized in tetrads.

A detailed taxonomic treatment will be given in an account of the palynological study of the whole section.

The results of the quantitative analysis are as follows:

Circumpollen	56%
Unidentified bisaccate pollens	27%
Monosaccate and Vesicate pollens	8%
Alete bisaccate pollen	7%
Ovalipollis group	1%
Taeniate bisaccate pollen	0.5%
Trilete spores	0.5%

The following taxa have been recognised (the recognised taxa are listed in Fig. 1 and the most significative miospore are illustrated in Plate 1):

Monosaccate:
- *Enzonalasporites vigens* Leschik, 1956 (Pl. 1, fig. 1)
- *Vallasporites ignacii* Leschik, 1956 (Pl. 1, fig. 2-3)
- *Patinasporites densus* (Leschik, 1956) Scheuring, 1970 (Pl. 1, fig. 6)
- *Zonalasporites cinctus* Leschik, 1956
- *Pseudoenzonalasporites summus* Scheuring, 1970 (Pl. 1, fig. 4-5)

Bisaccate:
- *Samaropollenites speciosus* Goubin, 1965 (Pl. 1, fig. 9)
- *Ovalipollis pseudoalatus* (Thiergart, 1949) Schuurman, 1976 (Pl. 1, fig. 7)
- *Chordasporites* spp.
- *Lueckisporites* spp.
- *Lunatisporites acutus* Leschik, 1956
- *Klausipollenites* sp.
- *Alisporites/Falcisporites* spp.

Circumpolles:
- *Camerosporites secatus* Leschik, 1956 (Pl. 1, fig. 12)
- *Partitisporites maljawkinae* (Klaus, 1960) Van der Eem, 1983 (Pl. 1, fig. 11)
- *Partitisporites novimundanus* Leschik, 1956
- *Partitisporites quadruplicis* (Scheuring, 1970) Van der Eem, 1983
- *Corollina* aff. sp. A (*sensu* Schuurman, 1977) (Pl. 1, fig. 10)

The combined occurrences of *Enzonalasporites vigens*, *Vallasporites ignacii*, *Patinasporites densus*, *Pseudoenzonalasporites summus*, *Samaropollenites speciosus* and *Camerosporites secatus* are indicative of Tuvalian age (Late Carnian).

This palynoflora is nearly identical to that described by Visscher & Krystyn (1978) in the Carnian-Norian transition sequence of Monte Triona, Sicily, corresponding to the boundary between the ammonoid Tropites subbullatus and Anatropites bereichi Zones (Krystyn, 1974, Tuvalian 2-3 boundary). A microfloral association containing all the taxa found in sample DGA 101 was described from a Carnian evaporite succession in Albania (Cirilli & Montanari, 1994) at a stratigraphic level attributed to the Tuvalian. The same taxa are found from Litwin & Ash (1993) in the Chatham Group, Deep River Basin (North Carolina, USA), and are, with the exception of *Samaropollenites speciosus* (Dunay & Fisher, 1974), present in the Chinle Formation and Dockum Group (SW USA). Fisher & Dunay (1984) reported the presence of *Samaropollenites concinnus*, a form similar to *S. speciosus*, in a microflora from the Blue Mesa of Arizona, which contains all the taxa found in sample DGA 101.

Dunay & Fischer (1978) reported a microflora with *Camerosporites secatus*, *Enzonalasporites vigens*, *Patinasporites densus*, *Vallasporites ignacii* and *Brodispora striata* (*Pseudoenzonalasporites summus* and *Samaropollenites speciosus* are not present) in levels of the Oppenitzer-Kalk (Austria) of Tuvalian age (Tropites subbullatus Zone). Following these authors, *Brodispora striata* has a particular biostratigraphic significance since it was found with the above mentioned association only in the Late Carnian Arden Sandstone of England (Clarke, 1965; Fisher, 1972; Warrington, 1970) and in some localities of the Chinle Formation and Dockum Group of SW USA (Dunay & Fisher, 1974; 1979; Fisher and Dunay, 1984). However, *Brodispora striata* was not found in the Late Carnian microfloral assemblages of the Southern Alps (this work), Sicily (Visscher & Krystyn, 1978) and Albania (Cirilli & Montanari, 1994). Therefore the presence of *Brodispora striata* could be attributed to palaeogeographical causes.

In sample DGA101 a form very similar to *Corollina* sp. A, *sensu* Schuurman 1977 and Van Erve 1977 (= *Circulina* sp. A) has also been recorded as cf. *Corollina* aff. sp. A. The specimens are organized in tetrads, have a subequatorial circular furrow, a smooth sexine and faint equatorial infrastriature; a distal pseudopore is absent, or is ill-defined (Pl. 1, fig. 10).

Palaeogeography and Palaeoenvironment.

The palynological assemblage reported here shows a noteworthy likeliness with the Onslow Microflora (Dolby & Balme, 1976). The latter is a mixed association with elements belonging to the Gondwana and to the Laurasia continents and is different to the high latitude boreal and austral microfloral associations. All the taxa found in sample DGA101 are present in the Onslow Microflora but in different proportions. Bisaccate pollen such as Sulcatisporites are prevalent in the Onslow Microflora, while circumpolles are most abundant in sample DGA101.

Visscher & Van der Zwan (1981) identified three Late Triassic floristic zones: a northern one characterized by *Camerosporites* and *Ovalipollis*, a middle one with *Camerosporites*, *Ovalipollis* and *Samaropollenites*, and a southern one with *Camerosporites* and *Samaropollenites*. Since the DGA101 microflora includes Camerosporites, Ovalipollis and Samaropollenites it belongs to the middle belt, known mainly from localities in North Africa.

The DGA101 microflora consist almost entirely of circumpolles, bisaccate and monosaccate pollens, which belong to the typical triassic conifers; only one spore was observed.

The monosaccate forms have been found associated with the conifer *Brachyphyllum* (Van Konijnenburg-Van Cittert, 1971). The circumpolles show affinities with Cheirolepidaceae; in fact *Corollina* was found in association with the conifer *Hirmeriella* (Francis, 1983; Van Konijnenburg-Van Cittert, 1971).

The pollen, particulary the circumpolles, are typical xerophytic elements, which indicate an arid climate (Cirilli & Montanari, 1994; Visscher et al., 1994). Aridity is also indicated by the total lack of miospore produced by hygrophytic plants (ferns or equisetales).

This is in agreement with the position of the Mediterranean region near the palaeotropic, where the climate was arid and warm during the Late Triassic (Robinson, 1973). The presence of gypsum in the Upper Carnian of Carnia (Pisa, 1971) and of Aupa valley (Bianchin et al., 1980) is additional evidence of aridity (Hallam, 1984).

The microflora is representative of the vegetation living at or near the site where the reptiles walked leaving their tracks. This is indicated by the relatively high number of tetrads, as these usually disarticulate during prolonged transport and generally form a very low proportion of a palynomorph association.

Acknowledgements.

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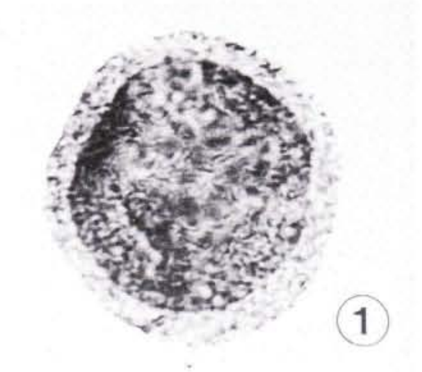
PLATE I

The slide collection. Coordinates of the figured specimens were taken with the England Finder using Leitz Wetzlar no. 5345 with attached camera. All the slides are housed in the Dipartimento di Geologia, Paleontologia e Geofisica of the University of Padova. 1) *Enzonalasporites vigens* Leschik, 1956, (45 μm); Slide Dogna1 II, G 31/4; 2-3) *Vallasporites ignacii* Leschik, 1956 (48 μm); Slide Dogna 1 II, W 40/1; 4-5) *Pseudoenzonalasporites summus*, Scheuring,1970 (38 μm); (4, single grain, Slide Dogna 1 V, L 46/1; 5, tetrad, Slide Dogna1 V, N 46); 6) *Patinasporites densus* (Leschik, 1956) Scheuring, 1970, (40 μm), Slide Dogna1 III, K 39/1; 7) *Ovalipollis pseudoalatus* (Thiergart, 1949) Schuurman, 1976 (length 81 μm), Slide Dogna1, III, M 42/1; 8) *Lueckisporites* sp. (48 μm), Slide Dogna1, S 48/3; 9) *Samaropollenites speciosus* Goubin,1965, (length 62 μm), Slide Dogna1 I, S 34/3. 10) cf. *Corollina* aff. sp. A (sensu Schuurman, 1977), (diameter of single grain in tetrad is 38 μm), Slide Dogna1 II, K 41/1; 11) *Partitisporites maljawkinae* (Klaus, 1960) Van der Eem, 1983, (diameter in single grain in tetrads is 40 μm), Slide Dogna1 V, D 41/4; 12) *Camerosporites secatus* Leschik, 1956, (45 μm), Slide Dogna1 IV, G 31/4.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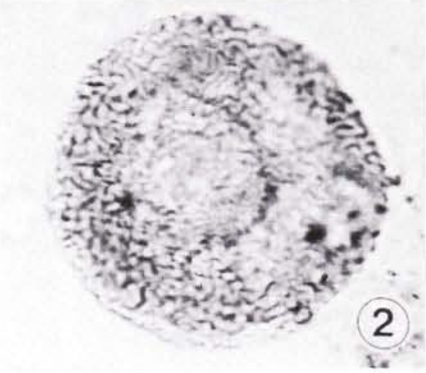
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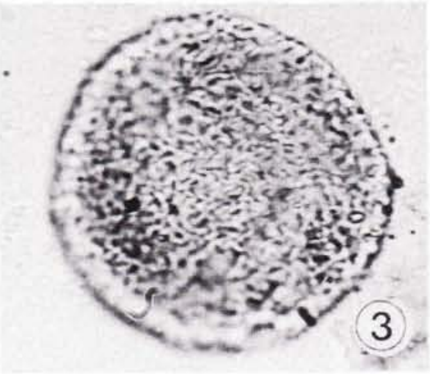
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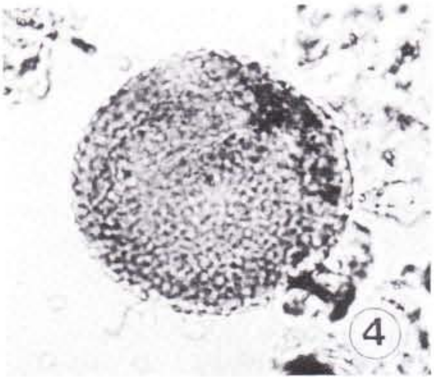
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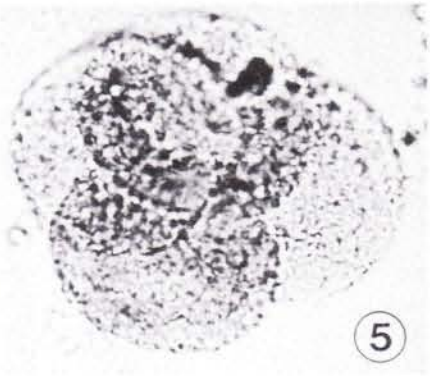
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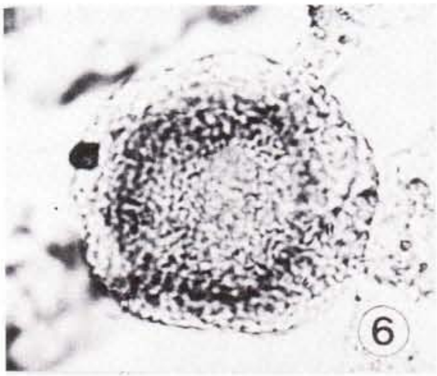
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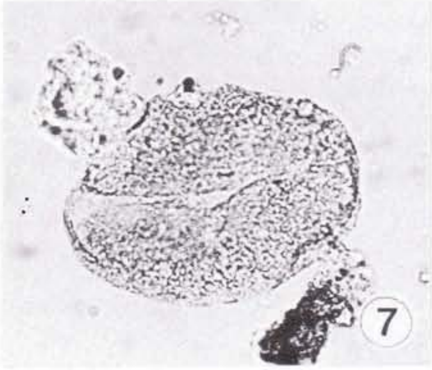
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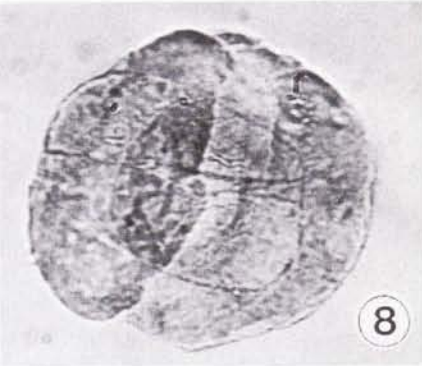
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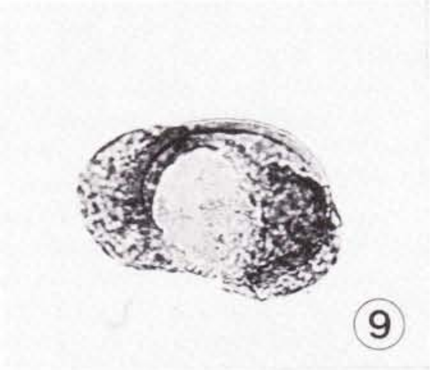
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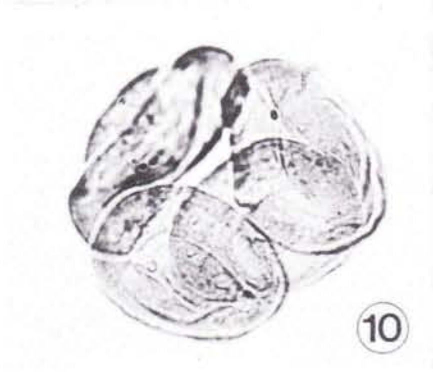
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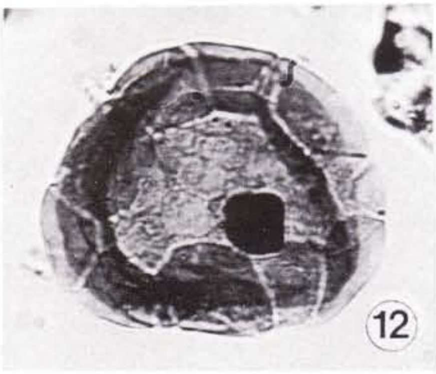
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